IMPROVED STEAM TURBINE LEAKAGE CONTROL WITH A BRUSH SEAL DESIGN

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Modified version of a presentation given by Ryan Pastrana at the recent Texas A&M Turbomachinery Symposium, September, 2001.

GE has installed approximately 70 brush seals in the field (in 9 machines).

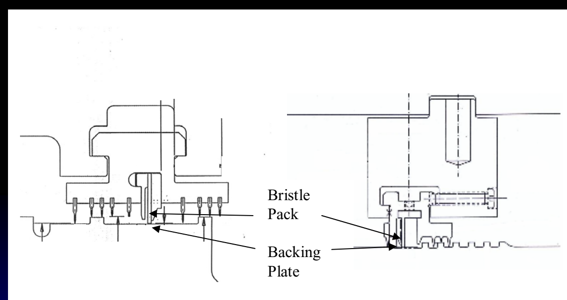
Being designed into new units as well as retrofits.

INTRODUCTION

- Performance Benefits
- Design Parameters
- System Considerations
- Laboratory Testing
- Field Experience
- Conclusion

Typical Design Characteristics

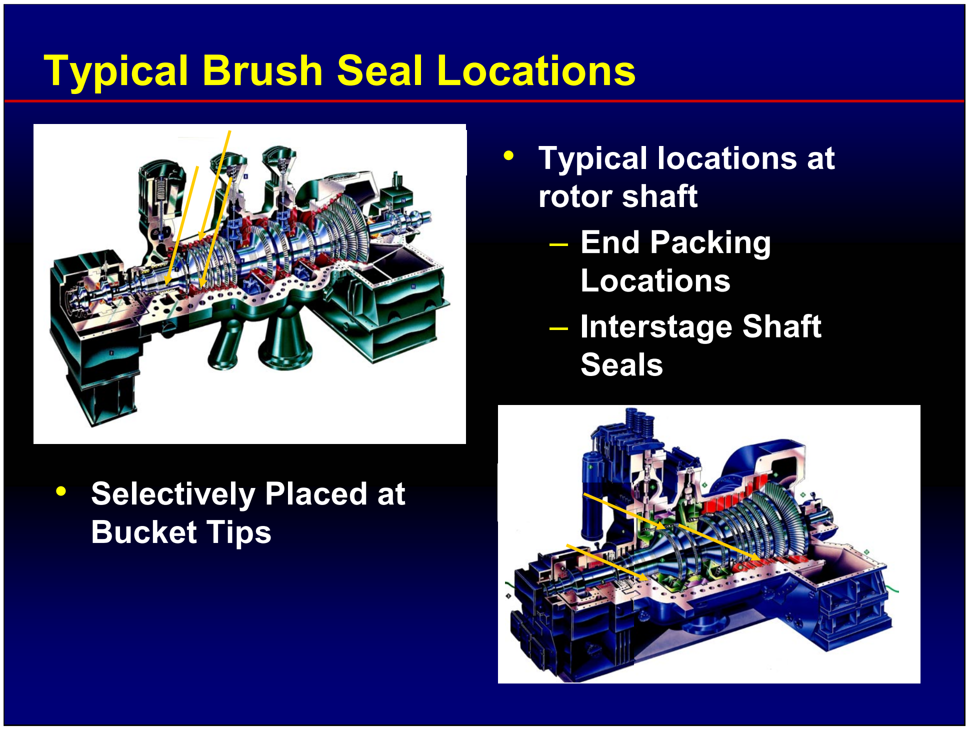
- Standard Labyrinth Seal Ring is Machined to Fit Brush Seal
- Insert Design Comprised of Bristle Strip – Groove in Labyrinth Ring serves as Backing Plate



Two configurations:

-Conventional brush seal fitted into existing labyrinth packing ring.

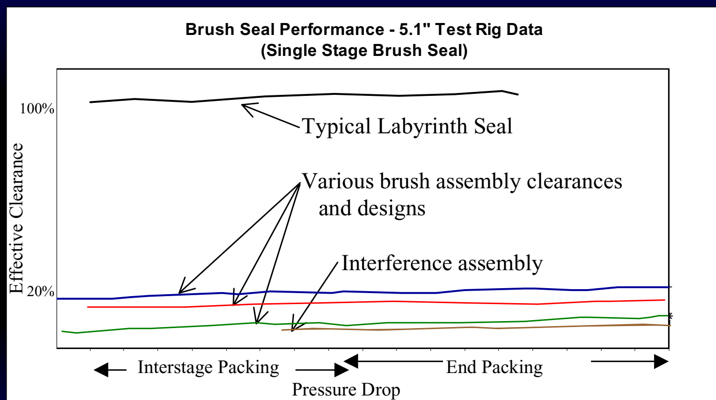
- New design - the pack is welded to side rails and the strip is slid into a slot in the packing ring. The side of the slot serves as the backplate. Can be rolled to diameter for cycle time savings.



Typical High Pressure section may have 8-12 turbine stages.

Typical brush seal application would be one brush at each interstage location, and 3-6 brush seals at end packing locations.

Reduced Leakage Rates



Brush Seal Clearance 20% of Typical Labyrinth Seals or Lower

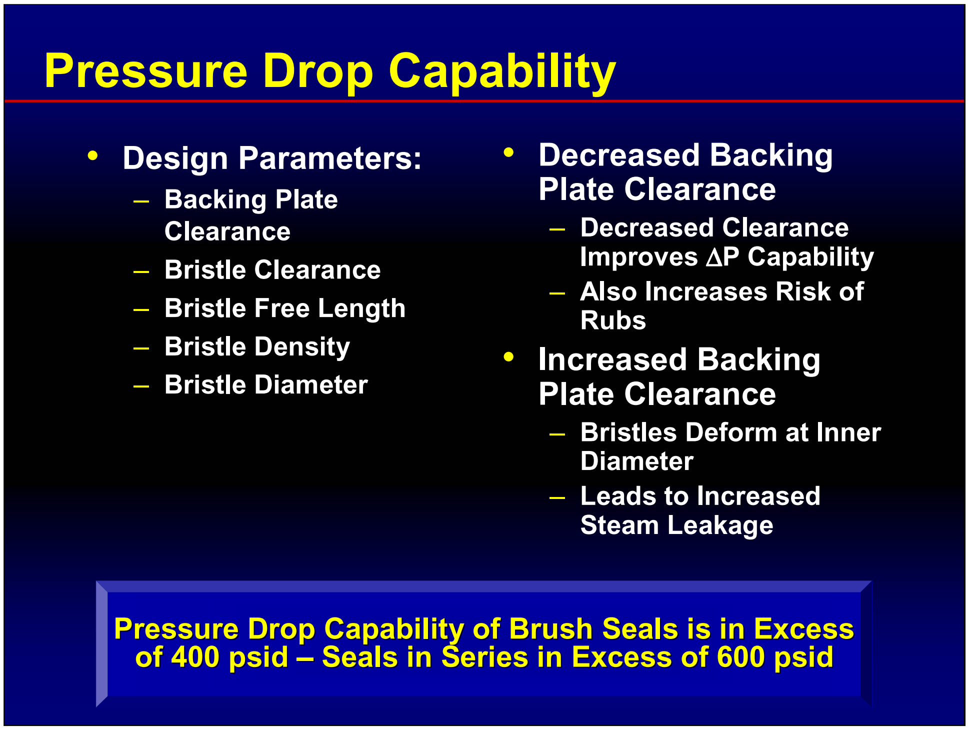
Performance Benefits

	Utility ST	Industrial ST
Interstage	0.5-1.2% HP section efficiency; 0.1-0.2% unit heat rate	0.2-0.4% efficiency
End Packing	0.1-0.2% unit heat rate	0.4-0.8% efficiency
Bucket Tip	0.5-1.0% HP section efficiency; 0.1-0.2% unit heat rate	0.7-1.1% efficiency

Utility Steam Turbine is typically rated at 400-800 MW.

Industrial ST is typically 50-150 MW.

The performance benefit of brush seals in ST's makes them a significantly worthwhile investment in the majority of Utility and Industrial units.

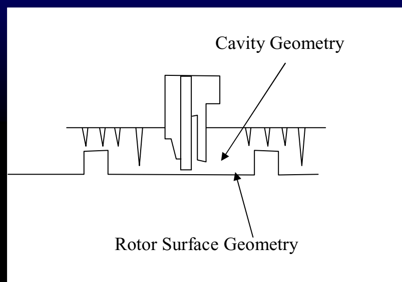


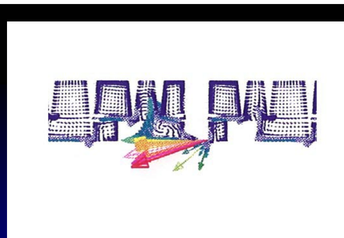
Typical pressure drop across interstage seal is 100-400 psid.

End packing seals typically up to 600 psid.

Can be up to 2000 psid at inlet end of ST; currently working on ways to handle this.

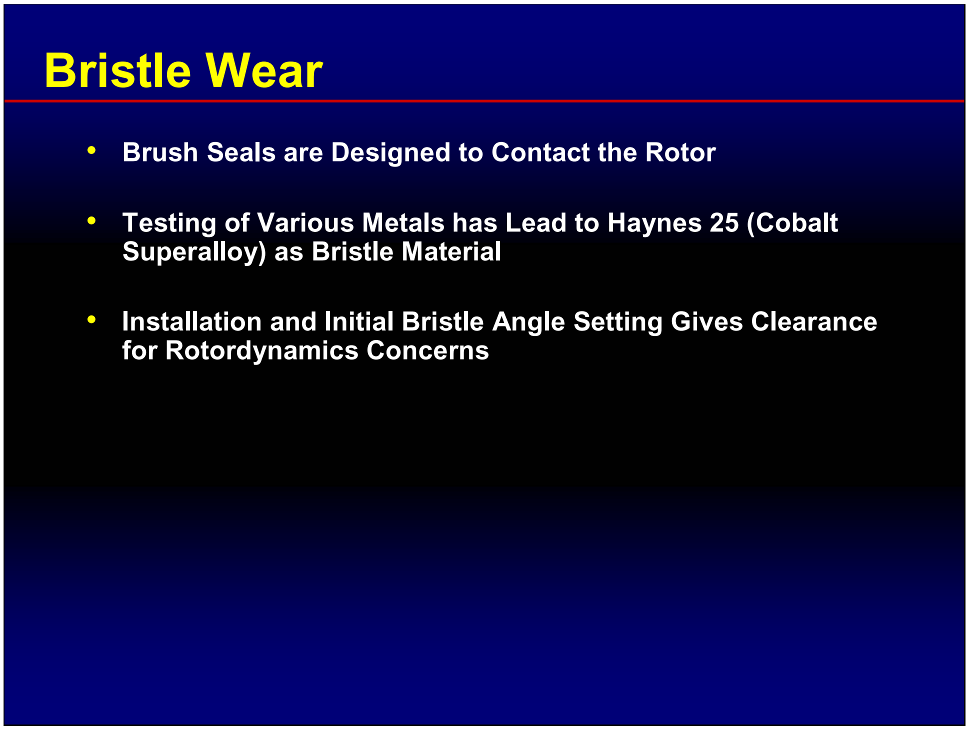
Bristle Stability





- **CFD Model of Brush Seal with Velocity Vectors**
- **Design of Upstream Cavity Key to Reducing Bristle Flutter**
- **Poor Designs Lead to High Cycle Fatigue of Bristles**

Bristle aerodynamic stability is an important design consideration.

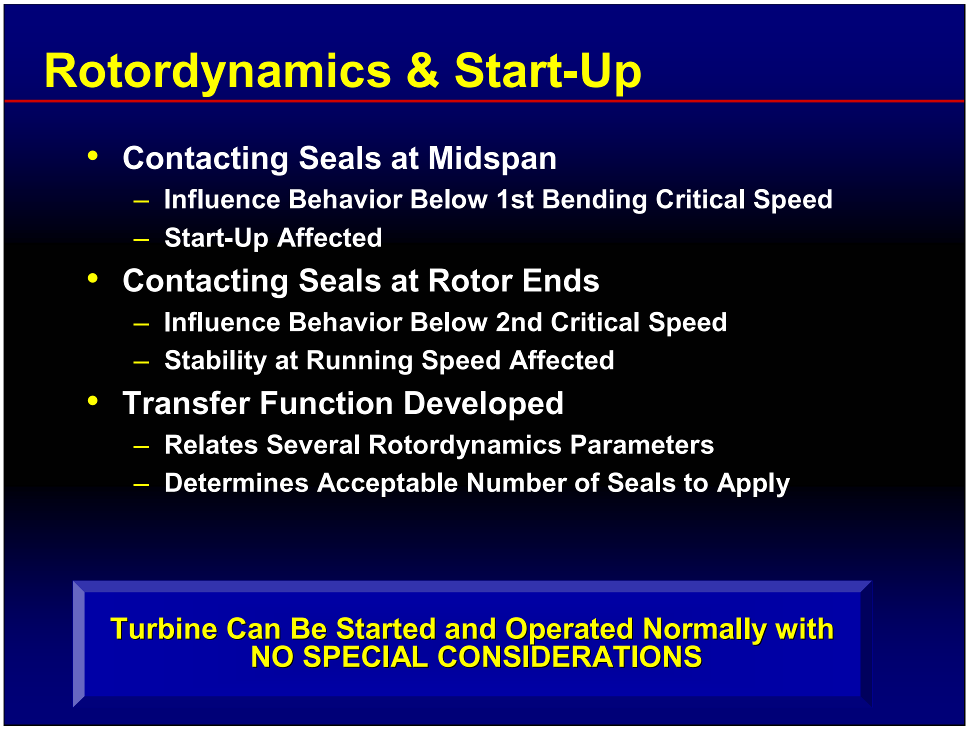


Haynes 25 is standard bristle material for ST applications.

Used on uncoated CrMoV rotor.

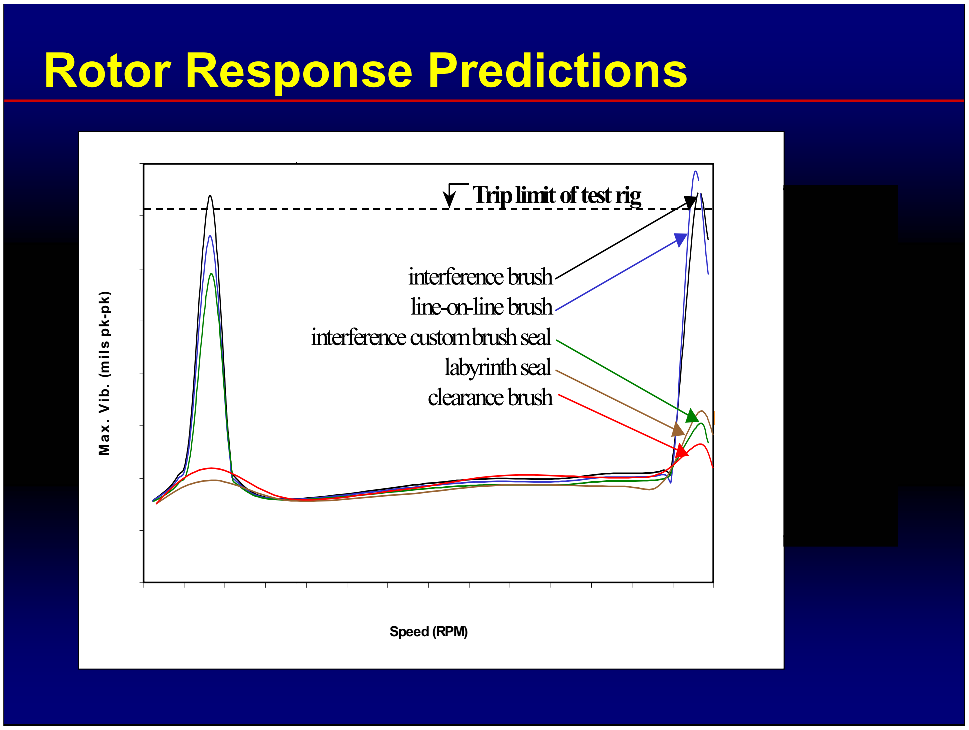
Temperatures range from 500-1050 F in high pressure turbine section.

Initial Angle Setting Allows for Clearance During Start-Up, and At Normal Operation, Steam Blow Down Pushes Bristles into Contact.



Rotordynamics is a very important consideration in how many seals are applied, at which locations, and with what level of assembly clearance/interference.

GE has developed a tool to assess rotordynamic impact; validated through lab testing and field experience.

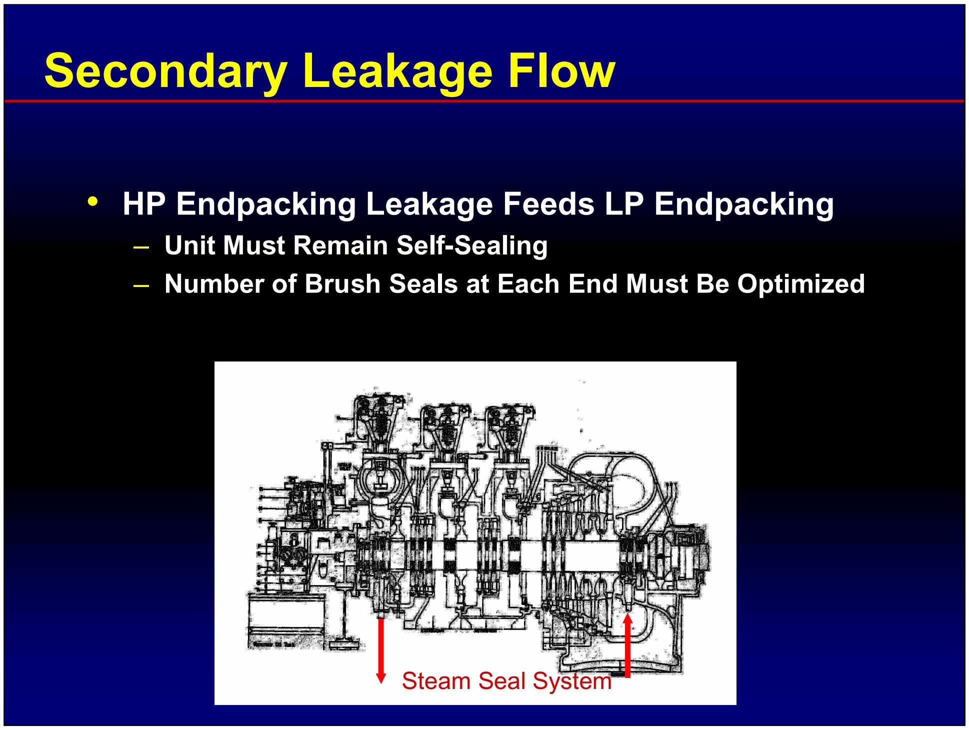


Steam Turbine solid, flexible shaft is sensitive to rub-induced heating and possibility of resultant rotor ‘bow”, which results in rotor vibrations.

Seals concentrated near rotor midspan affect rotor during startup (passing through critical speed). Seals near rotor ends tend to affect rotor at speeds just below 2nd critical speed. (ST’s typically run between the 1st and 2nd critical speeds.

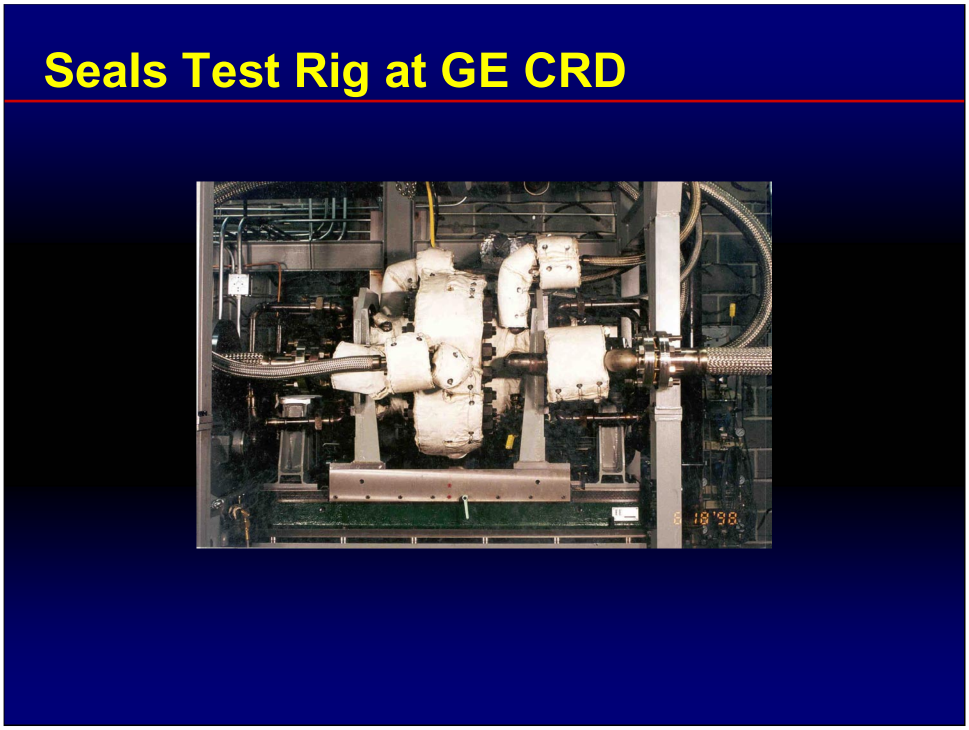
Impact on rotordynamic response is reduced with increasing assembly clearance.

Brush seals assembled with clearance; blowdown results in minimal contact of bristles to rotor, but significant performance improvement.



End packing brush seals must be integrated into the overall unit sealing system.

High Pressure end leakage is used to seal Low Pressure end; need to apply brush seals selectively to balance the system.



Rig capable of testing in 1200 psi, 750 F Steam
or 450 psi, 1000 F Air

Capable of 800 ft/s surface speed (36000 RPM).

5.1” shaft supported on tilting pad journal bearings; can be run above 1st and 2nd critical speeds to evaluate rotordynamics.

Rig is used for leakage and wear testing of ST, GT, and AE brush and labyrinth seals.

Steam Turbine Test Vehicle

Located in Lynn, MA.

Fully Instrumented Test Vehicle Allows for Pressures, Temperatures to be Measured at Discrete Radial Positions at each stage.

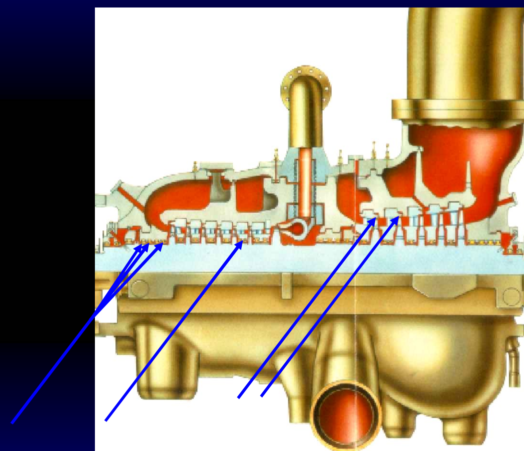
Velocity profiles at specified locations measured.

Back to back performance testing with brush seals in a STEAM ENVIRONMENT validates predictive methods.

Used for validation testing of brush seal performance predictions.

FIELD EXPERIENCE

- Opposed Flow High Pressure/Intermediate Pressure Turbine
- Brush Seal Locations at HP Endpacking, Interstage Shafts, and at Bucket Tips



9 machines in the field with approximately 70 brush seals.

Fleet leader has 32000 hours.

Two unit inspections this year:

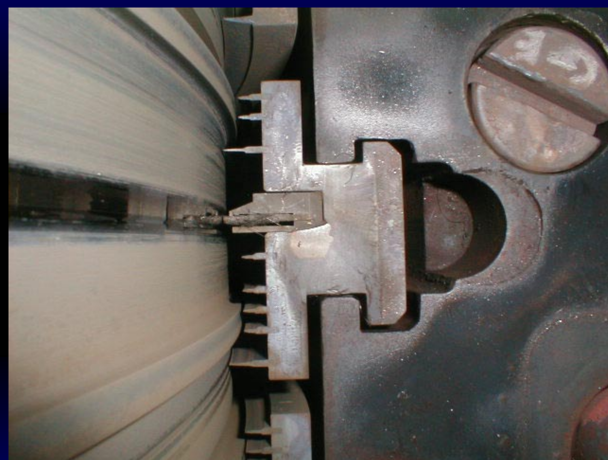
- One unit after 3 years (10 seals – all seals looked good, but replaced)
- One unit after 1.5 years (Seals looked good and returned to service)

End packing seals (3 brushes shown).

Polishing of rotor surface.

Minimal brush wear observed.

HP Shaft Seals



Note the polished rotor. Not only in this view, but throughout the circumference, the bristles survived. Bristle density is good and clearance (no wear) maintained. These were reinstalled after the outage.

Bucket Tip Seals

Tip seal in this unit looked very good. This end segment is slightly gnarled at the end, but along the circumference, the bristles survived. Note that over bucket tips, gaps between cover sections or radial steps at the junction of adjacent cover sections are important design considerations.

CONCLUSION

- Performance Benefits Up to 1.2% on Total Output Due to Reduced Leakage Rates for Industrial Sized Machines
- Design Characteristics Well Understood
- Consideration of the Turbine as a System is Very Important
- Analytical Predictions and Extensive Lab Testing Have Been Verified with Field Experience

Latest Inspections Show Excellent Results